PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

REC'D 1 3 JAN 2006

WIPO   PCT

Applicant's or agent's file reference P005272-PCT	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/BR2004/000114	International filing date *(day/month/year)* 14.07.2004	Priority date *(day/month/year)* 15.07.2003

International Patent Classification (IPC) or national classification and IPC

H02P23/00, H02P27/00, H01R9/24

Applicant

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1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

3. This report is also accompanied by ANNEXES, comprising:

   a. ☒ *sent to the applicant and to the International Bureau)* a total of 20 sheets, as follows:

      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).

      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

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4. This report contains indications relating to the following items:

   ☒ Box No. I   Basis of the opinion

   ☐ Box No. II   Priority

   ☐ Box No. III   Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

   ☐ Box No. IV   Lack of unity of invention

   ☒ Box No. V   Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

   ☐ Box No. VI   Certain documents cited

   ☐ Box No. VII   Certain defects in the international application

   ☒ Box No. VIII   Certain observations on the international application

Date of submission of the demand 16.05.2005	Date of completion of this report 10.01.2006
Name and mailing address of the international preliminary examining authority: European Patent Office - Gitschiner Str. 103 D-10958 Berlin Tel. +49 30 25901 - 0 Fax: +49 30 25901 - 840	Authorized Officer Roy, C Telephone No. +49 30 25901-573

Box No. I   Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐   This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

   Description, Pages

1-3	as originally filed
4-16	received on 16.05.2005 with letter of 16.05.2005

   Claims, Numbers

1-26	received on 16.05.2005 with letter of 16.05.2005

   Drawings, Sheets

1/5-5/5	as originally filed

   ☐   a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐   The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐   This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages   ,
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

   *   If item 4 applies, some or all of these sheets may be marked "superseded."

Box No. V   Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-9,11-16,24-26
	No:	Claims	10,17-23
Inventive step (IS)	Yes:	Claims	1-9,11-16
	No:	Claims	10,17-26
Industrial applicability (IA)	Yes:	Claims	1-26
	No:	Claims	

2. Citations and explanations (Rule 70.7):

   see separate sheet

Box No. VIII   Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V
Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:
D1: US-A-5 325 037 (JEONG JAE H) 28 June 1994
D2   EP-A-0 312 686 (GULTON IND INC) 26 April 1989
D3: US-A-5 450 521 (R W REDLICH) 12 September 1995

The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claims 10, and 17-23 is not new in the sense of Article 33(2) PCT and because the subject-matter of claims 24-26 does not involve an inventive step in the sense of Article 33(3) PCT.

V.1 The document D1 discloses a method/system comprising :
- a motor (s. fig. 3, BM2), fed by a total voltage (VC) controlled by an electronic control central (4), the total voltage being proportional to a network voltage,
- the electronic control central comprises a voltage detection circuit (s. fig. 4) detecting the network voltage, comprising a first detection circuit (s. fig. 4, OP1) and a second detection circuit (s. fig. 4, TR1);
- the electronic control central making a first and second network voltage measurement at a first and a second moments of measurement, the two moments of measurements being different, and at a first and a second voltage network level (s. fig. 5, zero cross + reference voltage);
- the second voltage detection circuit (TR1) being a comparison circuit generating a square wave having a transition moment when the second level of voltage has been reached is generated (see fig. 5 curves (c) and (d) and fig. 4, col. 4, l. 58-68);
- the electronic control central calculates the value of the network voltage measured in function of the measurement time being the lag time between the first and second moments of measurement (see fig. 5: T1, T2 and T3) and obtains a value of a proportional network voltage (measured voltage), compares the lag time with a pre-established time (T2) and alters the value of the total voltage proportionally to the value of the proportional network voltage (s. col. 5, l. 20-22).

Moreover the voltage detecting circuit (9) measures the network voltage at established first (zero crossing) and second (reference voltage, s. fig. 5) levels of voltage and the electronic control central includes a time counting device (microprocessor) that compares the lag time (T1, T2, T3) with a pre-established time (T2) and alters the total voltage proportionally, wherein the total voltage is increased when the lag time is longer than the pre-established time and the total voltage is decreased when the lag time is shorter than the pre-established time (T2)

V.2 The subject-matter of claim 1 differs from the method of D1 in that the total voltage is altered in function of the difference between the value of a proportional network voltage calculated in a present cycle of the network voltage and the value of the proportional network voltage *calculated in the previous cycle* of the network voltage.

This feature is neither known nor rendered obvious from any available prior-art and solves the problem of providing an alternative solution to the solution of D1 where the total voltage is altered in function of a difference between a calculated value and a constant predetermined value (T2).

Thus the subject-matter of claim 1 is new and inventive in the sense of Article 33(2) and (3) PCT.

V.3 Since all features of claims 10 and 17-23 are known from D1 (see item V.1.1 above), the subject-matter of claim 10 and of claims 17-23 is not new.

V.4 Since claims 11 and 12 contains the characterizing feature of claim 1 (see item V.2 above) or a corresponding feature, the subject-matter of claims 11 and 12 is new and involves an inventive step in the sense of Article 33(3) PCT.

V.5 When looking for a solution for providing a constant energy amount to the compressor of D3 despite fluctuations in the AC voltage the person skilled in the art would contemplate the possibility of implementing the teaching of D1 and he would then arrive to a system according to claims 24-26 without exercise of inventive skill.

Thus the subject-matter of claims 24-26 does not involve an inventive step in the sense of Article 33(3) PCT.

Re Item VIII
Certain observations on the international application

VIII.1 Although claims 1 and 10 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

cluding whether the voltage level applied to the motor should be altered or not;

- Controlling the stroke of the piston of a linear compressor, allowing the piston to advance as far as the end of its mechanical stroke, even under conditions of extreme load, without allowing the piston to collide against the cylinder top, even in the presence of external disturbances from the energy feed network;

- Controlling the stroke of the piston of a linear compressor, preventing oscillations in the maximum displacement of the piston, which impair the efficiency of the compressor, for any operation capacity of the compressor, even in the presence of external disturbances from the energy feed network;

- Implementing a simple solution for industrial-scale production.

These objectives are achieved by means of an electric motor movement controlling method, the electric motor being fed by a total voltage proportional to an alternate network voltage, the method comprising the steps of: making a first measurement of level of the network voltage at a first moment of measurement; making a second measurement of level of the network voltage at a second moment of measurement; calculating the value of the derivative of the voltage values measured in function of the first and second moments of measurement, to obtain a value of a proportional network voltage; and altering the value of the total voltage fed to the motor, proportionally to the value of the proportional network voltage, the total voltage being altered in function of the difference between the value of a proportional network voltage calculated in a present cycle of the network voltage and the value of the proportional network voltage calculated in the previous cycle of the network voltage.

The method further comprises steps of altering the value of the total voltage in function of the difference between the value of the proportional network voltage calculated in a present semi-cycle of the network voltage and the value of the proportional network voltage calculated in the previous semi-cycle of the network voltage.

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A further objective of the present invention is achieved by means of an electric motor movement controlling method, the electric motor being fed by a total voltage proportional to an alternate network voltage, the method comprising the steps of: measuring the network voltage at a first

5   moment of measurement and at a first level of the network voltage; measuring the network voltage at a second moment of measurement and at a second level of the network voltage, the first level of the network voltage and the second level of the network voltage having different levels of voltage the second moment of measurement being different from the first moment of measurement;

10   urement; generating a square wave having a transition moment when the second level of voltage has been reached; measuring a lag time between the between the occurrence of the first level of the network voltage at the first moment of measurement and the transition moment at the second moment of measurement, comparing the lag time with a pre-established time; altering

15   the value of the total voltage proportionally to the value of the proportional network voltage.

Still a further objective of the is achieved by means of an electric motor movement controlling system, the system comprises an electronic control central, the electric motor is fed by a total voltage controlled by the elec-

20   tronic control central, the total voltage being proportional to an alternate network voltage, the electronic control central including a voltage detecting circuit that comprises a first voltage detecting circuit that detects a first level of the network voltage and a second voltage detecting circuit that detects the second level of the network voltage and the electronic control central being

25   arranged to measure the first level of the network voltage at a first moment of measurement and the second level of the network voltage at a second moment of measurement, the second voltage detecting circuit being arranged to signal the passage of the level of the network voltage at the second level of voltage through a voltage comparator, the voltage comparator generating a

30   square wave having a transition moment, the lag time being measured between the occurrence of the first level of the network voltage and the transition moment, the electronic control central being arranged to calculate the

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value of the values of the network voltage measured in function of the measurement times measured and obtain a value of a proportional network voltage, the electronic control central being arranged to alter the value of the total voltage to a value of corrected total voltage, proportionally to the value of

5   a proportional network voltage.

Brief Description of the Drawings

The present invention will now be described in greater detail with reference to an embodiment represented in the drawings. The figures show:

- Figure 1 is a block diagram of the system of the present inven-

10   tion, illustrating the respective interconnection upon application to a compressor and a cooling system;

- Figure 2 is a block diagram of the system of controlling the movement of a piston according to the present invention upon application to a linear compressor;

15   - Figure 3 is a block diagram of the algorithm for control of the system for controlling the movement of a piston of the present invention;

- Figure 4 illustrates the control network of the system of controlling the movement of a piston of the present invention;

- Figure 5 is an electric diagram of a voltage-detecting circuit us-

20   ed in the system of the present invention;

- Figure 6 shows a graph of an input and output signal of the generator by the voltage-detecting circuit, for various levels of input voltage (nominal voltage, nominal voltage + 10%, nominal voltage – 10%);

- Figure 7 shows a graph of the lag time of the output signal of

25   the voltage-detecting circuit in function of the variation of the network voltage;

- Figure 8 illustrates the points where the network voltage is measured according to the teachings of the present invention;

- Figure 9 illustrates two different situations of network voltage, and the points of measurement made; and

30   - Figure 10 illustrates a particular situation where the teachings of the present invention are applied.

Detailed Description of the Figures

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The present invention relates to a system, as well as a method of controlling an electric motor, being particularly applicable for controlling movements of a piston in a linear compressor.

As can be seen in figures 1 and 2, the system of controlling
5   movements of a piston according to the present invention comprises an electronic control 12, which monitors a network voltage V_{AC} and controls a total voltage V_T applied to an electric motor that drives a compressor 14, which may be applicable to a cooling system 15.

The electronic control 12, comprises an electronic control central
10   10 which, by means of a gate circuit 21 controls the conduction time of a switch set 11 (preferably *TRIACs*), to control the total voltage level V_T.

In figure 2, one can see that the control system of the present invention comprises, associated to the electronic control central 10, a voltage detecting circuit 50, which is electrically connected to the network voltage
15   V_{AC}, so that the respective value will be measured before its level is controlled by the switch set 11.

With this configuration the electronic control central 10 can control the level of the total voltage V_T applied to the motor, proportionally to the level of the network voltage V_{AC}, and thereby prevent the occurrence of an
20   overvoltage or undervoltage in the feed network, that might cause the compressor 14 to behave in an unexpected way.

In order to implement the use of the system and monitor the network voltage V_{AC} and thus decide whether to interfere or not in the level of the total voltage V_T, one should implement the control algorithm illustrated in
25   figure 3, according to the control network illustrated in figure 4.

As can be seen in figure 3, the value of the total voltage V_T comprises the sum or subtraction of a value of a piston voltage V_P and a correction voltage V_V from the equation:

$$V_T = V_P \pm V_V.$$

30   The value of the piston voltage V_P is obtained from the values supplied by an external device, for example, a reference signal REF, which may indicate to which extent the compressor piston should be moved, espe-

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cially in the cases where the teachings of the present invention are applied on linear compressors, since in the latter the cooling capacity will depend upon the excursion amplitude of the respective piston. The value of the reference signal may be a DC level transmitted to the electronic control device 10.

5   In this way, and position of reference DP_{REF} of the piston is established.

Another variable necessary to establish the value of the piston voltage V_p is obtained by calculating the maximum desirable excursion point which the piston should advance without the risk of the latter colliding at the respective stroke end. Preferably, the value of the piston voltage V_P is ob-

10   tained by storing the value of the piston voltage V_P of the previous cycle. The value of maximum displacement DP_{MAX} should, therefore, be previously established based on the characteristics of the compressor 14.

Once the values of reference displacement DP_{REF} and maximum displacement DP_{MAX} have been obtained, the value of the piston voltage V_P

15   can be obtained, since the latter is a function of the difference between the values obtained, that is to say, between the calculated error E_{DP}.

The other component of the total voltage V_T, the value of the correction voltage V_V, will be obtained according to the teachings of the present invention, by comparing the value of the network voltage V_{AC} with a previ-

20   ously established value to conclude that there is a need for correction of the respective value, that is to say, the value of the correction voltage V_V will be the difference itself between the voltage expected to be read and the network voltage V_{AC}. In this way, in the cases where the value of the network voltage V_{AC} is within the expected limits, the value of the correction voltage V_V will be

25   null, since there is no need to alter the value of the network voltage V_{AC}.

As can be seen in figures 8 and 9, this measurement principle is carried out by adopting a fixed value of voltage V_0 (or established voltage level V_0) and counting the required time for the network voltage VAC to reach this level. This, in reality, is the same as measuring the derivative of the net-

30   work voltage V_{AC} close to zero, to estimate the value of the network voltage.

Putting this into equations, the following conclusion is reached:

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$$V_{AC} = f\left(\frac{\partial V_0}{\partial t}\right), \; V_{AC} \text{ being proportional to } \frac{\partial V_0}{\partial t_0}$$

For constant ∂V_0 :

$$V_{AC} = f\left(\frac{1}{\partial t_0}\right)$$

V_{AC} is inversely proportional to ∂t_0

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$$V_{AC1} = f\left(\frac{\partial V_0}{\partial t1_0}\right)$$

$$V_{AC2} = f\left(\frac{\partial V_0}{\partial t2_0}\right)$$

For constant ∂V_0:

$$V_{AC1} = f\left(\frac{1}{\partial t1_0}\right)$$

$$V_{AC2} = f\left(\frac{1}{\partial t2_0}\right)$$

10

Thus, one may conclude that the value of the above demonstrated network voltage V_{AC} may be calculated on the basis of the established voltage level V_0 and by taking as a reference the value V_{AC1} and V_{AC2} illustrated in figure 9. In this way, by taking, for instance, the value of V_{AC1} as a

15   reference, one may conclude that the value V_{AC2} would be below the level of network voltage V_{AC} desired for a determined application, and the value of the total voltage V_T should be corrected. The value V_{AC} taken as a reference will be the value of voltage of the previous cycle or the mean of the previous cycles, which results in that the value of the voltage taken as a reference will

20   not be constant, since the objective is to correct an oscillation of a cycle of the network for the next cycle.

As demonstrated above, considering that for a constant voltage level by adopting the established voltage level V_0 equal for the two meas-

ures, thus having constant ∂V_0, it is sufficient to measure only the time passed between two points measured by the voltage detecting circuit 50 and to detect which is the real voltage level from an equation or table of values.

In order to reach the voltage value necessary to correct the total
5   voltage V_T, the value of the correction V_V should be obtained, which, in practice, will be a proportional network voltage V_{AC}'; on the other hand, the respective value will be directly related to the value of the input voltage V_{AC}. In the same way as explained above, the value of the network voltage V_{AC} should be obtained from measurements of the previous network voltage V_{AC},
10   or from the mean of the measurements of the previous network voltages V_{AC}.

Mathematically, the value of the proportional network voltage V_{AC}' is reached by the following operation:

$$V_{AC}' = f\left(\frac{\partial V_0}{\partial t}\right)$$

15   As can be seen from the equation, the value of the proportional network voltage V_{AC}' is obtained by means of the derivative of voltage values obtained in function of the time passed between the measurements.

In order to implement such an equation in practice, it is enough to carry out two measurements of voltage and two measurements of time, as
20   exemplified in figure 10, so that one can proceed with the respective derivative, that is to say, one should preferably measure the network voltage V_{AC} at a first moment of measurement $t1_0$ to define a first measurement of level V_{t0} and then measure the network voltage V_{AC} at a second moment of measurement $t2_0$, defining a second measurement of level V_{t20}.

25   Once these values have been obtained, one proceeds with the equation below:

$$V_{AC}' = f\left(\frac{V_{t20} - V_{t10}}{t2_0 - t1_0}\right)$$

that is to say, by subtracting from the first and second measurements of level
30   V_{t10}, V_{t20} and dividing the result by the subtraction of the values of the first and second moments of measurement $t1_0$, $t2_0$, and the value ∂t is obtained

by subtracting the values of the first and second moments of measurement $t1_0$, $t2_0$.

From this control algorithm the readings of the input voltage should be stored at every semi-cycle of the network voltage V_{AC} and com-
5 pare the present reading with the previous one (or with the previous ones), and alter the value of the output to compensate for the network voltage V_{AC}, thus preventing a variation in the maximum piston displacement from occur-ring, since this variation might lead to a mechanical impact of the piston with the cylinder top or to a loss of efficiency of the system.

10 For instance, one may opt for carrying out a number of meas-urements on different cycles of network voltage V_{AC} and store the obtained values in the electronic control central 10, carrying out the derivative of the obtained values subsequently in order to reach a value of the proportional network voltage V_{AC}'.

15 In order to implement the use of the concepts of the present in-vention, a method is provided by which the network voltage V_{AC} can be moni-tored and conclude that there is a need to make some adjustment in the level of the total voltage V_T.

The method includes the steps of measuring the network voltage
20 V_{AC} at a first moment of measurement $t1_0$, and designated such a measure-ment as first level measurement V_{t10}.

Then the network voltage V_{AC} should be measured at a second moment of measurement $t2_0$. In the same way, the value of these measure-ments may be designated as a second level measurement V_{t20}.

25 Once these values are obtained as described above, the value of the derivative of the voltage values is calculated and measured in function of the measurement times $t1_0$, $t2_0$, to obtain the value of a proportional network voltage V_{AC}' and, finally, alter the value of the total voltage V_T fed to the mo-tor proportionally to the value of the proportional network voltage V_{AC}'.

30 One of the ways of proceeding, in practice, with the step of ob-taining the value of the proportional network voltage V_{AC}' may be by means of the following steps:

A lag time t_D is measured between the occurrence of the measurement of the first moment of measurement $t1_0$ and the occurrence of the measurement of the second moment of measurement $t2_0$. In this way, one can know which maximum level of the network voltage V_{AC} is required in or-

5   der to conclude that there is a need for correction in the value of the total voltage V_T.

For this purpose, it is enough to compare the lag time t_D with a pre-established time t_P, the latter being determined by the electronic control central 10, and one may proceed with the elevation of the total voltage V_T if

10   the lag time t_D is longer than the pre-established time t_P, or with reduction of the total voltage V_T if the lag time t_D is shorter than the pre-established time t_P.

In practice, it is recommendable to consider the value of the pre-established time t_P as the measurement of the lag time t_D of the previous cy-

15   cle or the mean of the previous cycles.

The simple comparison of the lag times t_D with the pre-established time t_P is opted when the conditions are more appropriate for this, but one may carry out the above steps when the circuits used in the embodiment demand the need to proceed with the derivative described before.

20   As far as the system for implementing the method of the present invention is concerned, it should comprise the electronic control central 10 to control the electric motor and the voltage detecting circuit 50 to measure the value of the network voltage V_{AC}.

As described in the method, the electronic control central 10 will

25   make the first level measurement V_{t10} of the network voltage V_{AC} at a first moment of measurement $t1_0$, making the second level measurement V_{t20} of the network voltage V_{AC} at the second moment of measurement $t2_0$, and these measurements may be carried out as times goes by and as the cycles of the network voltage V_{AC} take place.

30   The derivative of the values of the network voltage V_{AC} measured in function of the times of measurement $t1_0$, $t2_0$ measured and the obtention of the value of the proportional network voltage V_{AC}' will be carried out by the

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electronic control central 10, which, in function of the value of the network voltage V_{AC} will alter the value of the total voltage V_T to a value of corrected total voltage V_T' to prevent the piston from going beyond the foreseen point and to prevent impacts.

5   The voltage detecting circuit 50 should comprise the first voltage detecting circuit 51 to detect the first level of network voltage V_{M1} and the second voltage detecting circuit 52 to detect the second level of the network voltage V_{M2}.

Preferably, the first voltage detecting circuit 51 is adjusted to 10   measure the first level of network voltage V_{M1} at the time of the respective passage by a zero level (or zero of the voltage ZT) and the second voltage detecting circuit 52 to measure the second level of network voltage V_{M2} between the zero level of the network voltage V_{AC} and the maximum level of the network voltage V_{ACM}. In this way, two different measurements of level are 15   obtained, and thus it is possible to proceed with the derivative of the measured values.

The lag time t_D is registered between the occurrence of the measurement of the first level of the network voltage V_{M1} and the occurrence of the measurement of the second level of the network voltage V_{M2}. These 20   measurements are carried out by the voltage detecting circuit 50, which will transmit the respective occurrences to the electronic control central 10. A time counting device comprised in the electronic control 12 compares the lag time t_D with the pre-established time t_P, and alters the total voltage V_T proportionally to the lag time t_D. The value of the total voltage V_T will be raised to a 25   value of corrected total voltage V_T' if the lag time t_D is longer than the pre-established time t_P and reduced to a value of corrected total voltage V_T' is the t_D is shorter than the pre-established time t_P. When the value of the lag time t_D is equal to the pre-established time, it will not be necessary to make an alteration in the total voltage V_T, since, in this case, the network voltage V_{AC} 30   will be in ideal conditions. In other words, in these conditions, when the lag time t_D is null, the value of the total voltage V_T will be the value of the piston voltage V_P.

Within the teachings of the present invention, one can see in figures 2 and 5 that the first and second voltage detecting circuits 51, 52 are directly connected to the network voltage V_{AC}, the respective outputs ZT and TR being fed to the electronic control device 10.

5   The first voltage detecting circuit should preferably be configured as illustrated in figure 5, that it so say, a configuration where the zero level of the voltage ZT of the network voltage V_{AC} is detected. In this case, the output ZT of this circuit will oscillate between 0 V and Vcc, which in the example of figure 6 is of 5V, a difference existing between the value of 5V and the read

10   signal (see curve 55) due to the drop in voltage on the diode D1 (Scales 0.5 V/div – 0.5 ms/div). In this way, the signal ZT may be directly interpreted by the electronic control circuit 10.

The second voltage detection circuit 52 comprises a voltage divider R_2/R_3, which lowers the level of the network voltage V_{AC} to an adequate

15   level to be processed by the electronic control central 10. This may be seen in the curves illustrated in figure 6, which correspond, respectively, to the measurements made with voltage levels of 242V (see curve 62), 220V (see curve 63) and 198V (see curve 64), these curves illustrating, respectively, a situation of V_{AC} in overvoltage, expected voltage and undervoltage, and the

20   value of the voltage VT should be mediated/corrected whenever there is oscillation from a cycle to another.

A comparator 56 of the second voltage detecting circuit 52 will detect the passage of the level of the network voltage V_{AC} by a point that is pre-determined and controlled by the reference voltage Vref, to signalize at

25   the output TR that the reference voltage level has been reached. The result of this is the generation of square waves 62', 63' and 64', which correspond, respectively, to the values of the network voltage V_{AC} measured. The comparator 56 may be embodied, for instance, by using an operational amplifier or another type of equivalent device.

30   The voltage comparator 53 will generate a square wave having a transition moment, the lag time t_D being measured between the occurrence of the first level of the network voltage V_{M1} and the transition moment.

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This may be observed in figure 6, where the lag times t_{D1}, t_{D2}, t_{D3} are illustrated, and which correspond to the examples of voltage at a level of 242V (curve 62), 220V (curve 63) and 198V (curve 64), respectively.

The voltage values measured by the first and second voltage
5   detecting circuits 51, 52 correspond to the first level of the network voltage V_{M1} and to the second level of network voltage V_{M2} described above, and are interpreted in the way foreseen in the method of the present invention. One can see, in this example, that the value of the first level of the network voltage V_{M1} is equal to zero (see indication with reference 65 in figure 6).

10   With respect to the first and second moments of measurement $t1_0$, $t2_0$, they will be registered from the moment of detection of the zero level of the voltage ZT and the detection of the reference voltage TR, and should be proceeded with the counting of the time between the respective occurrences so that the lag time t_D is compared with the pre-established time t_P
15   and alter the total voltage VT proportionally to the lag time t_D. As can be seen in figure 6 (see indication 65), in this example, the value of the first moment of measurement $t1_0$ is equal to zero, and the pre-established time t_P will be the mean of the defined time t_D of the previous cycle or the mean of the previous cycles.

20   Another way to embody the voltage detecting circuit 50 may comprise, for example, instead of the fist voltage detecting circuit 51 operating in conjunction with the second voltage detecting circuit 52, to detect the zero level of the voltage ZT and the reference level TR, a pair of circuits similar to the second voltage detecting circuit 52. In this option, it is enough that
25   the reference value of the comparator 56 can simply be adjusted at two different levels, so that the measurement said first and second levels of the voltage V_{M1}, V_{M2} can be made at the first and second moments of measurement $t1_0$, $t2_0$ and proceed with the derivative of the measurements and find the proportional network voltage V_{AC}'.

30   As a further way of embodying the voltage detecting circuit 50 to obtain the values of the first and second levels of the voltage V_{M1}, V_{M2} at the first and second moments of measurement $t1_0$, $t2_0$, one may foresee the use

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of a converter D/A. In this solution, the same measurements foreseen in the embodiments described above should be proceed, and the interpretation of the means made by the electronic control central 10 should be adapted, which will receive the digital number corresponding to the measurement

5 made by the converter D/A.

One of the ways of detecting which is the value of the network voltage V_{AC} from the measurement of the first and second voltage levels V_{M1}, V_{M2} is that one may opt for storing a table of values foreseen in the electronic control central 10 and from the value of the lag time t_D measured one can

10 conclude which is the value of the network voltage V_{AC}.

Thus, the second table below may accompany the example of figure 7.

V_{AC} [V]	t_D [ms]
246	2.36
242	2.63
220	3.00
198	3.57
176	5.00

One can note, in this example, that the value of the pre-

15 established time t_P is of 3.00 ms and the lag time t_D varying between 2.36 (characterizing overvoltage) and 5.00 (characterizing undervoltage).

The control over the total voltage VT may be made together with the control over the piston voltage V_P, supplied by a piston position control. In this way, one can actuate at the same time with an internal control, for exam-

20 ple, of a system involving a compressor with a control of the level of the network voltage V_{AC}, complementing the systems and resulting in a much more efficient and safe control.

Thus, with the teachings of the present invention, one prevents oscillations in the network voltage V_{AC} from interfering with the situation of

25 the electric motor, which, for instance, might cause mechanical collision of the piston with the top of the cylinder of the linear compressor, thus improv-

ing the reliability and the working life of the compressor, besides improving functioning stability of the compressor, preventing loss of efficiency caused by variation in the maximum displacement of the piston.

A preferred embodiment having been described, one should un-
5   derstand that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, which include the possible equivalents.

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CLAIMS

1. An electric motor movement controlling method, the electric motor being fed by a total voltage (V_T) proportional to an alternate network voltage (V_{AC}),

5   the method being characterized by comprising the steps of:

- making a first measurement of level (V_{t10}) of the network voltage (V_{AC}) at a first moment of measurement ($t1_0$);

- making a second measurement of level (V_{t20}) of the network voltage (V_{AC}) at a second moment of measurement ($t2_0$);

10   - calculating the value of the derivative of the voltage values measured in function of the first and second moments of measurement ($t1_0$, $t2_0$), to obtain a value of a proportional network voltage (V_{AC}'); and

- altering the value of the total voltage (V_T) fed to the motor, proportionally to the value of the proportional network voltage (V_{AC}'), the total

15   voltage (V_T) being altered in function of the difference between the value of a proportional network voltage (V_{AC}') calculated in a present cycle of the network voltage (V_{AC}) and the value of the proportional network voltage (V_{AC}') calculated in the previous cycle of the network voltage (V_{AC}).

2. A method according to claim 1, characterized in that the value

20   of the total voltage (V_T) is altered in function of the difference between the value of the proportional network voltage (V_{AC}') calculated in a current semi-cycle of the network voltage (V_{AC}) and the value of the proportional network voltage (V_{AC}') calculated in the previous semi-cycle of the network voltage (V_{AC}).

25   3. A method according to claim 2, characterized in that the value of the proportional network voltage (V_{AC}') is obtained from the equation:

$$V_{AC'} = f\left(\frac{\partial V_0}{\partial t}\right)$$

wherein ∂V_0 is obtained by subtracting the first and second measurements of

30   level (Vt_{10}, Vt_{20}), and the value of ∂t is obtained by subtracting the values of the first and second moments of measurement ($t1_0$, $t2_0$).

4. A method according to claim 2, characterized in that after the step of obtaining the value of proportional network voltage (V_{AC}') one foresees a step of:

5
- measuring the lag time (t_D) between the occurrence of the measurement of the first moment of measurement ($t1_0$) and the occurrence of the measurement of the second moment of measurement ($t2_0$);

- comparing the lag time (t_D) with a pre-established time (t_P);

- altering the value of the total voltage (V_T) proportionally to a value of the proportional network voltage (V_{AC}'), the value of proportional

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network voltage (V_{AC}') being proportional to the lag time (t_D), when the lag time (t_D) is different from a pre-established time (t_P).

5. A method according to claim 4, characterized in that the pre-established time corresponds to the lag time (t_D) of the previous cycle of the network voltage (V_{AC}).

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6. A method according to claim 5, characterized in that the in the step of altering the total voltage (V_T) the elevation of the total voltage (V_T) if the lag time (t_D) is longer than the pre-established time (t_P) is foreseen.

7. A method according to claim 6, characterized in that in the step of altering the total voltage (V_T) the diminution of the total voltage (V_T) if

20
the lag time (t_D) is shorter than the pre-established time (t_P) is foreseen.

8. A method according to claim 7, characterized in that the value of the total voltage (V_T) corresponds to a difference between the value of the piston voltage (V_P) and the value of the proportional network voltage (V_{AC}'), the value of the piston voltage (V_P) being previously established.

25
9. A method according to claim 8, characterized in that the total voltage (V_T) feeds an electric motor of a compressor, the compressor comprising a piston.

10. An electric motor movement controlling method, the electric motor being fed by a total voltage (V_T) proportional to an alternate network

30
voltage (V_{AC}), the method being characterized by comprising the steps of:

- measuring the network voltage (V_{AC}) at a first moment of measurement ($t1_0$) and at a first level of the network voltage (V_{M1});

- measuring the network voltage (V_{AC}) at a second moment of measurement ($t2_0$) and at a second level of the network voltage (V_{M2}), the first level of the network voltage (V_{M1}) and the second level of the network voltage (V_{M2}) having different levels of voltage;

5   - the second moment of measurement ($t2_0$) being different from the first moment of measurement ($t1_0$);

- generating a square wave having a transition moment when the second level of voltage (V_{M2}) has been reached;

- measuring a lag time (t_D) between the between the occurrence

10   of the first level of the network voltage (V_{M1}) at the first moment of measurement ($t1_0$) and the transition moment at the second moment of measurement ($t2_0$);

- comparing the lag time (t_D) with a pre-established time (t_P);

- altering the value of the total voltage (V_T) proportionally to the

15   value of the proportional network voltage (V_{AC}').

11. A method according to claim 10, characterized in that the pre-established time (t_P) corresponds to the lag time (t_D) of the previous cycle of a network voltage (V_{AC}).

12. A method according to claim 10, characterized in that the

20   pre-established time (t_P) corresponds to a mean of lag times (t_D) of the previous cycles of the network voltage (V_{AC}).

13. A method according to any one of claims 11 or 12, characterized in that the value of the proportional network voltage (V_{AC}') is proportional to the lag time (t_D).

25   14. A method according to claim 13, characterized in that, in the step of altering the total voltage (V_T), it is foreseen to raise the total voltage (V_T) if the lag time (t_D) is longer than the pre-established time (t_P).

15. A method according to claim 14, characterized in that, in the step of altering the total voltage (V_T), it is foreseen to lower the total voltage

30   (V_T) if the lag time (t_D) is shorter than the pre-established time (t_P).

16. A method according to claim 15, characterized in that the value of the total voltage (V_T) corresponds to a difference between the value

of a piston voltage (V_P) and the value of the proportional network voltage (V_{AC}'), the value of the piston voltage (V_P) being previously established.

17. An electric motor movement controlling system being characterized in that:

the system comprises an electronic control central (10),

the electric motor is fed by a total voltage (V_T) controlled by the electronic control central (10), the total voltage (V_T) being proportional to an alternate network voltage (V_{AC}),

the electronic control central (10) including a voltage detecting circuit (50) that comprises a first voltage detecting circuit (51) that detects a first level of the network voltage (V_{M1}) and a second voltage detecting circuit (52) that detects the second level of the network voltage (V_{M2}) and

the electronic control central (10) being arranged to measure the first level of the network voltage (V_{M1}) at a first moment of measurement ($t1_0$) and the second level of the network voltage (V_{M2}) at a second moment of measurement ($t20$),

the second voltage detecting circuit (51) being arranged to signal the passage of the level of the network voltage (V_{AC}) at the second level of voltage (V_{M2}) through a voltage comparator (53), the voltage comparator (53) generating a square wave having a transition moment, the lag time (t_D) being measured between the occurrence of the first level of the network voltage (V_{M1}) and the transition moment,

the electronic control central (10) being arranged to calculate the value of the values of the network voltage (V_{AC}) measured in function of the measurement times ($t1_0$, $t2_0$) measured and obtain a value of a proportional network voltage (V_{AC}'),

the electronic control central (10) being arranged to alter the value of the total voltage (V_T) to a value of corrected total voltage (V_T'), proportionally to the value of a proportional network voltage (V_{AC}').

18. A system according to claim 17, characterized in that the first voltage detecting circuit (51) is adjusted to measure the first level of the network voltage (V_{M1}) at the time of the respective passage by a zero level.

19. A system according to claim 18, characterized ion that the second voltage detecting circuit (52) is adjusted to measure the second level of the network voltage (V_{M2}), the second level of the network voltage (V_{M2}) being located between the zero level of the network voltage (V_{AC}) and a

5 maximum level of the network voltage (V_{ACM}).

20. A system according to claim 19, characterized in that the electronic control central (10) comprises a time counting device that compares the lag time (t_D) with a pre-established time (t_P) and to alter the total voltage (V_T) proportionally to the lag time (t_D).

10 21. A system according to claim 20, characterized in that the electronic control central (10) is arranged to generate a value of a proportional network voltage (V_{AC}'), value of voltage (V_{AC}') being proportional to the value of the lag time (t_D), and the electronic control circuit (10) is arranged to alter the value of the total voltage (V_T) to a value of corrected total voltage

15 (V_T) proportionally to the value of the proportional network voltage (V_{AC}') when the lag time (t_D) is different from the pre-established time (t_P).

22. A system according to claim 21, characterized in that the electronic control central (10) is arranged to raise the value of the total voltage (V_T) to a value of corrected total voltage (V_T') if the lag time (t_D) is longer

20 than the pre-established time (t_P).

23. A system according to claim 27, characterized in that the electronic control central (10) is arranged to lower the value of the total voltage (V_T) to a value of corrected total voltage (V_T') if the lag time (t_D) is shorter than the pre-established time (t_P).

25 24. A system according to claim 23, characterized in that the total voltage (V_T) feeds an electric motor of a compressor, the compressor comprising a piston,

the electronic control central (10) comprising a value of defined voltage (V_P), the defined voltage (V_P) being proportional to an error (E_{DP}) be-

30 tween a reference displacement position (DP_{REF}) and a maximum displacement (DP_{MAX}) of the piston,

the reference displacement position (DP_{REF}) being proportional to

the position of the piston in the compressor, and

the maximum displacement (DP_{MAX}) being proportional to a desirable displacement of the piston in the compressor.

25. A system according to claim 24, characterized in that the signal generating circuit (50) comprises a D/A converter.

26. A compressor having a system characterized by comprising a system such as defined in claims 17 to 25.